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Ecological corridors, connecting science and politics: the case of the Green River in the Netherlands

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Summary

1. During recent decades, the ecological corridor has become a popular concept among ecologists, politicians and nature conservationists. However, it has been criticized from a scientific point of view. In this paper we question why this concept has been accepted so readily in policy and practice.
2. We present a conceptual framework to analyse the rise of the concept, especially in the Netherlands. We have studied the Dutch literature from the period 1980–2005, including the main ecological journal *Landschap* (*Landscape*), policy documents and reports from the leading Dutch policy-orientated ecology research centre.
3. Many actors, including politicians, stakeholders and scientists, were involved in the development of the ecological corridor and the related National Ecological Network on the national and regional levels. The involvement of these actors changed the character of the concept into the multifunctional 'robust corridor'.
4. The ecological corridor was probably so influential because its vague and flexible character facilitated the coming together of various stakeholders and scientists. It also functions as a metaphor, applicable to well-known entities such as construction and transport. Finally, scientists from the policy-orientated research centre were able to link the concept to fundamental science, policy and practice. In some stages of the policy-defining process, however, conflicts arose between the proponents of scientific soundness and those of social robustness that reduced the role of scientists.
5. *Synthesis and applications*. To make ecological concepts both scientifically sound and socially robust, several changes must take place in current interactions between ecology and society. First, during concept development it requires the existence of extensive, largely interactive peer groups with clearly defined relationships between scientists and non-scientists. Secondly, the concepts should be flexible and relatable to relevant knowledge, insights, values and practices. Thirdly, several feedback loops between science and non-science should be set up during the various stages of concept development and implementation.

Key-words: conservation, ecological management, ecology-based decision-making, socially robust science, stakeholders participation

Introduction

The concept of the ecological corridor, in short a physical or biological strip connecting areas that allow the movement of species, has become popular in recent decades in fields of ecological restoration, applied ecology and conservation biology (Rosenberg, Noon & Meslow 1997; Jongman, Külvik & Kristiansen 2005). Many politicians and nature conservationists also took up the idea quickly, as is illustrated by the Nature 2000 initiative aimed at protecting and connecting nature areas in the European Union (Jongman, Külvik & Kristiansen 2005). In the United States the Wild Lands project advocated the creation of corridors to allow for dispersal and migration of organisms (Foreman *et al*. 1995).

Despite this popularity, political resistance has been reported from North America and Europe because of the high costs of these corridors or opposition from stakeholders (Simberloff *et al*. 1992; Rientjes & Roumelioti 2003; Bennet & Mulongoy 2006). The ecological corridor concept has also been criticized scientifically. It is often regarded as unclear and ambiguous because of different conceptualizations. In addition, ecologists have criticized its poor theoretical and empirical foundations (Simberloff *et al*. 1992; Shrader-Frechette & McCoy 1993).

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In this paper we investigate how the corridor concept has been accepted in policy and practice by considering the mechanisms legitimizing ecological corridors. First, we present a conceptual framework and our research questions. We focus subsequently on the research and development stage of the concept of ecological corridors. We then analyse a decision-making process and the implementation of a particular corridor on the regional level in the Netherlands. In this country a highly ambitious plan for a National Ecological Network was presented at the end of the 1980s, which included many new ecological corridors. This plan has become a model for numerous plans elsewhere in Europe (van der Zouwen & van Tatenhove 2002). Finally, we discuss our findings in relation to conservation decision-making.

Concepts and questions

The ecological corridor concept is linked to both scientific and societal contexts. This is not exceptional in ecology. Landscape, water and nature management are important political enterprises with a high need for scientific knowledge. In the second half of the 20th century, ecologists were therefore involved in policy-related research and advising on projects (Kwa 1989; Underdal 1989). Insights from ecology have been applied successfully in fishery and environmental management. Furthermore, politicians have used concepts such as ecosystem or umbrella species to underpin the need for policy measures or standard setting (Kwa 1989; Simberloff 1998; Disco 2002). However, it appeared that these ecological insights cannot always fulfil the expectations of policy-makers (Kwa 1989). Although it is true that the relatively young discipline of ecology lacks thoroughly empirically tested ecological theories, a more fundamental reason is the complexity of the multiple interactions between organisms and their environment. This often leads to different interpretations and theories, which may collide with solution-driven policy rationalities. To take an example, environmental managers like to know whether the drainage of nutrient-rich water will affect the quality of an ecosystem. However, there is often a lack of data about the influence of eutrophication on species, no time for experiments, and the ecosystem is not understood well enough for a policy-satisfying answer. Moreover, most ecosystems are affected by human activity, which implies a role for policy-related knowledge, but ecological understanding itself is not sufficient to answer such human-centred questions. As a result there is not only a need for more sound science, but also the need for specific and other knowledge related to specific practices, and for procedures to deal with uncertainties.

Based on empirical and theoretical studies, many scholars from the field of science and technology studies argue that such policy-related knowledge should be distinguished from traditional academic science (Funtowicz & Ravetz 1993; Jasanoff 1993; Nowotny, Scott & Gibbons 2001). They use terms such as 'regulatory science', 'postnormal science' or 'contextualized science'. Societal contextualization does not preclude the need for scientific qualification, but the involvement of the context implies additional criteria and judgement procedures to guarantee scientific soundness, on one hand, and what we call social robustness and, by consequence, societal acceptance on the other hand (Jasanoff 1993; Nowotny, Scott & Gibbons 2001). A certain scientific domain may be defined as socially robust if it is accepted widely by politicians, stakeholders and citizens as appropriate for the framing and/or solution of a certain societal problem. Following Nowotny, Scott & Gibbons (2001) and Jasanoff (1993), we formulate three characteristics of social robustness.

First, an extended forum of actors is involved in the process of knowledge production and quality assessment. Experts and scientists from different disciplines, users of the knowledge and affected people are part of this extended forum. Often new institutions have to be introduced to function as science–policy interfaces, such as in the cases of climate change and sea management (Boehmer-Christiansen 1994; de Jong 2006). An extended forum should be regarded as an integral part of participative forms of 'good governance'.

Secondly, knowledge production requires the ability and willingness of each party, scientific and non-scientific, to cope with the knowledge and demands of the other parties. Clear procedures that make the relationships between several parties transparent must be applied. Involved actors have to consider each other's competing interpretations respectfully. At the same time a certain common ground and cohesion are needed to bind several actors and perspectives and to rise above pluriformity. For this, so-called 'boundary objects' are used, i.e. common practices, institutions or frameworks for interpreting the differently experienced worlds (Starr & Griesemer 1989). Such boundary objects are robust enough to bind several parties but flexible enough to enable these parties to maintain and legitimize their own interpretations or practices. Because they are linked to both scientific and non-scientific aspects they have a hybrid character, which makes them useful in the communication between the scientific community and the surrounding world.

Thirdly, knowledge production is interactive, integrative and reflexive. This means that empirical and observational evidence should not be restricted to laboratory-like conditions, but should also include real-world circumstances. As such, basic science is applied not only to a new context, but the context itself is part of the scientific process and will influence the choice of methodology, the level of interdisciplinarity, and so on. Testing, expanding and modifying the knowledge produced takes place in an interactive process between society and science.

What is regarded as scientific credibility or soundness? In general, scientists are regarded as credible if they are widely believed to have substantial amounts of knowledge, insight and skills in a certain domain. A certain domain of science is regarded as sound if the theories are consistent and coherent, if the central concepts and terms are well defined, if the theory is universally applicable and is tested by a sufficient number of adequate experiments or other data.

Obviously, several potential tensions can be identified between scientifically sound and socially robust science

(Jasanoff 1993; Gross 2002). For example, classic scientific norms require universalism, which implies the ideal of a context-free interpretation, whereas social robustness stresses context dependency. Scientific soundness derives its credibility from its system of peer-reviewing by scientists from the same discipline, whereas socially robust science also accepts quality assessments from scientists in other fields and even from non-scientists. Finally, scientific soundness implies unambiguous concepts and theories, whereas social robustness may lead to vagueness in order to be able to bind together different sorts of knowledge, values and interests.

Now we are able to formulate our questions more precisely. First, can the ecological corridor concept be considered as politically and societally successful? Secondly, to what extent is the concept considered scientifically sound? Thirdly, can the ecological corridor be seen as socially robust with respect to an extended and coherent forum, the relationships between science and non-science, and the reflexivity of knowledge building?

Scientific aspects

Theoretically, most authors link the concept of an ecological corridor to the equilibrium theory of island biogeography and to metapopulation theory (Perrow & Davy 2002). Equilibrium theory predicts that the number of species in an insular situation is in a dynamic equilibrium between local on-site extinction of resident species and stochastic immigration to the site by new species (MacArthur & Wilson 1967). Metapopulation theory suggests that populations consist of subpopulations and that there is a relationship between the suitable habitats of a certain population represented by a balance between the extinction of the subpopulation in occupied patches and the colonization of empty patches (Levins 1966). For these reasons, connecting structures or corridors are considered essential to enable migration, reduce extinction rates and to increase colonization rates.

Simberloff *et al*. (1992) stress that the role of ecological corridors varies considerably from species to species and from population to population. They argue that there are only a few useful studies available and general conclusions cannot yet be drawn. The study of the Florida panther, for example, shows that proposed corridor systems cannot always prevent extinction. There are also uncertainties about the functioning of corridors for other organisms (Simberloff & Cox 1987; Mann & Plummer 1995; Rosenberg, Noon & Meslow 1997). Predators, diseases and opportunistic species may profit from corridors, and corridors may facilitate an unexpected gene flow. Furthermore, to mention only two empirical studies, an 8-year study on epigeic arthropods shows almost no effect of a corridor on colonization (Gruttke & Kornacker 1995) and the general assumption of 'the wider-the-better principle' of corridors was challenged for the root vole (Andreassen, Halle & Ims 1996).

Another criticism is the vagueness of the concept. Simberloff *et al*. (1992) found very different definitions of the concept of corridors, including series of discrete refuges for waterfowl and underpasses to cross main roads. Rosenberg, Noon & Meslow (1997) mention streamside riparian areas, shelterbelts, forest remnants and fencerows, which may function in different ways. They conclude that as long as it is unclear whether the focus is on shape, habitat or dispersion, it is hardly possible to evaluate the importance of ecological corridors. Jongman, Külvik & Kristiansen (2005) demonstrate that the concept is linked both to cultural heritage and river ecosystem quality.

In response to these critics, adherents of the ecological corridor concept argue that at least 12 studies, mainly on birds, are in favour of the creation of corridors (Noss 1987; Beier & Noss 1998). They emphasize that the uncertainties and disadvantages of corridors can be resolved by management and additional research.

During recent decades more data have become available showing that corridors are very important in overcoming the problem of fragmentation (Bennett & Mulongoy 2006; Damschen *et al*. 2006). However, other researchers are still so sceptical that they have advised their governments not to create ecological corridors (Good 1998). To take just one critical example, a review on hedgerow corridors shows that the empirical evidence currently available is insufficient to evaluate their effectiveness as a conservation tool to promote the population viability of woodland fauna (Davies & Pullin 2007). A survey among European ecologists and conservationists reveals that the majority regard the concept of ecological corridors as sufficiently relevant and valid, but 23% of the respondents express reservations about its scientific basis (Rientjes & Roumelioti 2003). A main problem in interpreting the empirical findings correctly is that the studies differ considerably with respect to organisms, focus (migration, extinction, predation, time and space scales) and type of corridor (water or land, existing or newly created).

We may thus conclude that initially there was much uncertainty as to whether the concept of an ecological corridor could be seen as scientifically sound, using criteria such as 'clearness of the concept', 'consistency of the theoretical background' and 'empirical basis' and that doubts still remain.

Societal context

Notwithstanding these uncertainties, corridors have been considered seriously in nature conservation since the introduction of island theory and metapopulation theory (Simberloff & Abele 1976; Shrader-Frechette & McCoy 1993; Looijen 2000). In 1980, the International Union for the Conservation of Nature and Natural Resources (IUCN) adopted the idea of ecological corridors into its World Conservation Strategy (IUCN 1980) and in the United States and Europe the concept was soon accepted by governmental and non-governmental organizations (NGOs) (Simberloff *et al*. 1992; Jongman, Külvik & Kristiansen 2005). Ecologists working within NGOs, centres for applied science and governmental institutions have demonstrated much enthusiasm for the concept (Rientjes & Roumelioti 2003). As Simberloff & Cox (1987) state: 'corridors have been promoted outside the bounds of

mainstream science'; so it seems that the concept of corridors has been a successful societal enterprise. As an example of the role of societal context we will sketch the rise and implementation of the concept in the Netherlands.

DEVELOPMENT AT THE NATIONAL LEVEL

For the period 1980–2005, we studied national nature policy documents, reports from Alterra, the research institute for applied ecology and landscape design, and all volumes of the leading Dutch journal *Landschap* (*Landscape*) published by the Society for Landscape Ecological Research.

After its introduction in the Netherlands at the end of the 1970s, landscape ecologists discussed the relevance of ecological corridors for Dutch nature conservation (Opdam 1978; Brussaard & van der Weijden 1980; Saris 1984). The 1981 national nature policy document was already suggesting creating corridors between nature reserves as an additional aim in conservation, referring to new ecological insights (CRM & VRO 1981). The situation changed radically in 1989 when the new national nature policy document announced the creation of a National Ecological Network of 750 000 ha by connecting existing and newly developed nature reserves with more than 200 national and 40 transnational ecological corridors (LNV 1989a). The responsible Ministry of Agriculture, Nature Management and Fisheries found it necessary to start an offensive to save nature reserves because of large problems with eutrophication, acidification, parching and fragmentation. Nature reserves had to become more robust; that is, larger and more connected to other reserves. The plan was initiated by ecologists within this ministry and the relevant ecological theories were presented in a background document (LNV 1989b). The Alterra institute or one of its precursors was hardly involved (Visser 2006).

Many provincial authorities and private conservation organizations became enthusiastic because this new national plan could be used to create and plan new nature areas. Accordingly, many proposals for ecological corridors throughout the country were initiated. An evaluation study from 1997 by a precursor of the Alterra institute shows that 30% of the intended corridors had already been created, in line with the planning of the 1989 national nature policy document. However, it also reports that most projects paid no attention to the question of whether the corridors were really effective ecologically and that several provinces were resistant to the plans (Bak & Reijnen 1997).

Because of these problems, the Dutch government decided in 2000 to focus on 27 000 ha of 'robust corridors'. These robust corridors were regarded as better able to connect nature reserves and to cover multiple functions. In addition to the central objectives of enhancing the migration of animals such as the great bittern and red deer and of improving the cohesion of the National Ecological Network, these corridors also had to improve the historical cultural identity of the landscape, recreation opportunities, water management, and even agriculture (LNV 2000). By introducing this element of multifunctionality the government expected more support from provincial authorities and stakeholders and to reduce the implementation costs for the plans (Visser 2006). It was thought that in the case of large multifunctional corridors the lack of scientific information was less crucial (Opdam, Reijnen & Vos 2003). The government decided to stop subsidizing the implementation of hundreds of planned small corridors, except those which result in strong judicial or administrative problems if they were stopped. Later, the government was forced to ask Alterra for advice, in particular to select the ecologically most valuable small corridors as well (LNV 2004; Visser 2006). The corridor concept was thus transformed to make it socially stronger, but nevertheless ecological corridors were still regarded as an essential element of the National Ecological Network.

What about the scientific development during the same period? After a symposium of the Dutch Landscape Ecology Society in 1983 on ecological infrastructures, *Landschap* has published some 30 papers on dispersion, fragmentation, metapopulation theory and ecological corridors. Many landscape ecologists were positive about the corridor concept because insights from population ecology could be linked to concepts of landscape structure and to proposals for landscape design. However, some of them echoed international criticism in stressing that the concept of a corridor is rather vague – corridors can simply be hedgerows or narrow side ditches – and that it is risky to use such unsubstantiated concepts in conservation (Dekker & Knaapen 1986).

In 1987, Opdam, one of the leading Dutch corridor experts working at the Alterra Institute, stated that 'you cannot conclude from metapopulation theory that corridors are the only solution for the survival of populations' (Opdam 1987). Ever since, there has been an ongoing discussion on ecological corridors in *Landschap*, based on empirical studies. Some underpin the notion that corridors are useful for several species of fish and large mammals (Lammers 1989) or that models show that connections between nature reserves are necessary for the survival of metapopulations (Verboon, Opdam & Schotsman 1991). Others stress that ecological corridors do not work for many plants (van Dorp 1992) or that several corridors appear to be useless (Bal & Reijnen 1997).

In 2000 the Ministry of Agriculture, Nature Management and Fisheries presented the reports of two working groups consisting of researchers from Alterra and officials from ministries, provinces, water authorities and municipalities. Both reports conclude that ecological corridors are necessary, that there is insufficient knowledge, and that robust corridors may combine ecological and social functions (Beentjes & Koopman 2000; Pelk *et al*. 2000). These reports could function as the scientific and societal basis for the political shift towards the so-called robust corridors.

Almost immediately, Alterra published the *Handboek Robuuste Verbindingen* (*Handbook for Robust Corridors*) (Broekmeyer & Steingröver 2001), offering guidelines for the size and shape of ecological corridors based, as far as possible, on ecological information. The handbook describes detailed corridor conditions for 50 animal species (mainly butterflies, birds and mammals) and for several hundred flowering

plants. For instance, for the otter the corridor should be at least 50 m wide and consist of water and rough vegetation. The handbook picks up the political message, providing information on whether, when and how the corridors can be combined with recreation, water management and agriculture. The authors realize that corridors are not a panacea, emphasizing that they should be seen as just one of the strategies to counter the fragmentation of habitats and populations. Other approaches include improving habitat quality and enlarging nature reserves.

To help unravel the specific relationships between landscape structures and dispersion of species, Alterra commenced two studies. In one the institute designed guidelines for monitoring the corridors (Vos & Smulders 2004); the other study consisted of a survey of the literature and three empirical studies. The literature survey reveals that of 18 species (butterflies, mammals and amphibians), nine are strongly dependent on a dispersion corridor and nine either to some or no extent (Vos, Baveco & van der Veen 2005). The empirical studies show that corridors are not necessary *per se*, but that they can stimulate the dispersion of the wood mouse and the common frog.

Most of the policy-related scientific work was carried out by Alterra researchers familiar with the scientific weaknesses of the concept, but convinced that fragmentation was a problem for many species and that corridors could be helpful for certain species. The idea of a National Ecological Network was a successful political enterprise and to be seen criticizing these concepts was regarded as strategically dangerous (Visser 2006). Thus, for Alterra scientists the ecological corridor was barely acceptable from a scientific viewpoint but desirable from a nature conservation policy viewpoint.

This outline of the rise of the ecological corridor in the Netherlands demonstrates that many parties were involved in its development and determination, including both scientists and non-scientists. The concept and the related National Ecological Network appeared to be binding and stimulating concepts for these parties. From the development of an ecological corridor this led to the development of the multi-functional robust corridor.

IMPLEMENTATION ON THE REGIONAL LEVEL: THE GREEN RIVER

We now review the perception and judgement of the concept of ecological corridors on the regional level through the example of a proposed restoration project of an ecological water corridor in the northern part of the Netherlands during the period 2001–05. This is based on assessment of policy documents, structured interviews with key actors (listed in the Acknowledgements), and by observations gathered during a workshop on this wet corridor.

After the decision to fund a National Ecological Network according to the national nature policy document of 1989 (LNV 1989a), the provincial authorities were charged with its implementation from 1990 onwards. As a result, 900 corridors were planned in provincial schemes for ecological networks instead of the 200 intended in the national policy document (Visser 2006).

In the province of Groningen, most attention was paid to wet corridors because of developments in national water management after 1990, such as the need to combine requirements for flood safety, water transport and nature conservation. Besides the corridors mentioned in the official National Ecological Network plans and Provincial Ecological Network plans, ecologists and nature conservationists, sometimes together with a fishery organization, launched several additional plans. They stressed the importance of these plans for the migration of fish species, the quality of the landscape in relation to recreation and water management (Vegter 1997; IWACO 1999). At the same time, a consortium of large Dutch nature conservation organizations presented a national plan called *Veters los* (*Loosen the Laces*), proposing to restore old river and brook systems to enlarge riparian areas (Helmer, Van Beek & Schouten 1997).

Developing from these plans, the Green River plan was proposed by a coalition of nature protection organizations. This plan aimed to restore brook valleys in the northern part of the Netherlands (Het Drentsch Landschap *et al.* 2001). According to the Green River plan, the rainwater draining from the higher Pleistocene plateau in the province of Drenthe south of the city of Groningen would follow an hourglass-like pattern on its way to the Dutch Wadden Sea, a shallow part of the North Sea. The central part of this pattern would approach the city fairly closely on its western side through an already planned new industrial zone. After this narrow passage, the water would be guided into brooks throughout the countryside of the province of Groningen. The Green River plan won the support of the Algemene Nederlandse Wielrijders Bond (ANWB), the largest recreational organization in the Netherlands, because this plan also aimed to improve recreation facilities and the quality of life in Groningen (Het Drentsch Landschap *et al*. 2001). In the same year, similar ideas were presented by the Ministry of Agriculture, Nature Management and Fisheries (Geraedts 2001).

Both the province and the city of Groningen considered that restoring riparian habitats to brooks could be the new approach that would also fulfil nature conservation, water management and landscape quality aims. However, farmers and industrial parties wanted guarantees that such plans would not harm their interests. Some provincial and communal politicians were critical of the costs. Last but not least, the regional Water Authority was highly sceptical of the idea of water management through the restoration and construction of wet ecological corridors.

To ensure commitment and create a consensus, the provincial authorities initiated a number of workshops with regional and local authorities and stakeholders, assisted by several consultancies (Kuiper Compagnons 2001; Tauw 2003). Gradually, the Green River ecological corridor became linked to other issues within a rather complicated process of decision-making and different levels of government (community, province, region and state) with different visions and responsibilities becoming involved.

From interviews with the main actors, it appears that the stakeholders involved had different evaluations of nature and

water. Conservationists showed a preference for so-called wilderness nature, whereas the authorities and farmers preferred functional nature, i.e. nature that supported human interests such as recreation and transport, or more arcadian nature perspectives (van der Windt, Swart & Keulartz 2007). With respect to water, conservationists focused on restoring the old brook systems, provincial authorities stressed recreational and other functional aspects, while farmers were interested primarily in the safety and irrigation quality of water. However, during the decision-making process, communicative efforts on the part of the provincial authorities contributed to bridging these contrasting viewpoints. Nature conservationists and water authorities became aware that water storage could be combined with the restoration of brook valleys. In some parts of the proposed brook valley system, farmers were willing to manage ecological zones in a nature-friendly way; in other parts they asked for assurances that they could continue to develop rationalized forms of agriculture.

The role of the province was somewhat ambiguous, despite its aim to reach a wide consensus. The Green River plan was not completely in line with its own nature conservation and spatial policy in which little room was left for the development of new riparian systems (Provincie Groningen 1993, 2000). As a compromise, the provincial authorities proposed making a smaller ecological corridor, only 50 m wide instead of the 150 m in the Green River plan. The city of Groningen was also ambivalent, mainly because of the high costs. After intervention by the Green party in the city council, the city was forced to accept the Green River plan for this industrial area, with a width of 150 m in principle for the riparian zone. It is expected that substantial parts of the Green River plan will be implemented within a few years.

During the decision-making process on this regional and provincial level ecological knowledge played a role in legitimizing the concept of corridors, but on the operational level it played only a marginal role. For example, during one workshop towards the end of the decision-making process, the ecological backing of the Green River, particularly the width of the riparian corridor near the city of Groningen, was questioned without receiving convincing answers from ecologists and conservationists. Furthermore, according to usual practice, it is unlikely that monitoring programmes will evaluate the ecological functioning of the corridor (Commissie Beleidsonderzoek Natuur en Landschap 2001).

Thus scientists played only a minor role and it is still uncertain whether this Green River corridor will be adequate for the migration and survival of species. Nevertheless, Green River appeared to be an appealing metaphor that could unite the interests and values of multiple actors because it could fulfil several functions.

Discussion

Earlier we formulated three questions concerning the ecological corridor concept: its political and societal success, its scientific soundness and its social robustness. With respect to the first question it seems quite obvious that the ecological corridor concept in the Netherlands has been a political success. Societal resistance and ecological doubts could not prevent many stakeholders and authorities from working enthusiastically to establish ecological corridors and hundreds of corridors have been or will be built.

With respect to scientific soundness, some reservations must be made. As we have already noted, there have been intense debates on concepts derived from island theory and metapopulation theory, especially in the 1980s. At that time few data were available and the ecological corridor was a vague concept that could not be regarded as scientifically sound. Now, two decades later, there are better models and there is more evidence on the impact of fragmentation and the role of corridors for certain species and populations. It appears, however, that the role of corridors for many species and landscapes is still uncertain. Most ecologists agree that for only a relatively small group of organisms are there enough appropriate data available to design successful corridors. Also, although a handbook on ecological corridors does exist in the Netherlands, even today it can be disputed whether the ecological corridor is a sound scientific concept (Perrow & Davy 2002).

Considering social robustness, we found several interesting aspects regarding the ecological corridor. As the Dutch case demonstrates, many parties were involved during the process of knowledge production and there was a strong policy demand influencing the development of the concept. We may speak of an 'extended forum' involved in the acceptance and elaboration of the concept, in particular its transformation into a multifunctional and large corridor. The forum consists of scientific experts, politicians, conservationists, water managers, recreational organizations and other stakeholders such as fishermen.

We conclude that the concept of ecological corridors was able to unite many disparate groups, and as a consequence it has subsequently changed into a much broader concept covering different social and political functions. The interesting question here is how could the ecological corridor be so successful in this respect. A plausible factor is its vagueness. The term ecological corridor does not prescribe a certain size or function. It is a very flexible term that can be used by many people and groups for different landscapes, biotopes, species and populations. In this sense it is a boundary object: strong enough to bind and flexible enough to leave room for different operating forms and interpretations. Another aspect is probably its metaphorical power. Just as with the term 'system' in the case of 'ecosystem' (Kwa 1989), 'corridor' and the related term 'network' refer to analogous vital transport, communication and institutional structures in our society (Keulartz 2007).

However, it is remarkable that only a small group of scientists, mainly from the Alterra Institute and some landscape ecologists from the Society for Landscape Ecological Research, appeared to be key figures in the interface between policy-making and science. The society organized a symposium on ecological corridors in 1983 and its journal *Landschap* has published many related papers. The ministry responsible for nature management has sought advice from Alterra on the scientific foundation of ecological corridors and Alterra

has participated in several working groups considering the implementation. However, neither Alterra nor any other scientific body was really involved in the crucial stages of the policy-forming process, such as the decisions taken on the National Ecological Network and implementation in the provinces. So their influence was relatively limited to establishing the ecological basis of the concept of ecological corridors and they can be seen as legitimizing the implementation of the concept by policy-makers.

We stated earlier that socially robust science is characterized by reflection on the basic principles involved, the sources of knowledge and the relationship between knowledge and application during the process of knowledge production. Did this happen with the concept of the ecological corridor? Obviously, the Dutch case shows that there were repeated attempts to decide whether or not the ecological corridor concept was a proper scientific concept and how it could be related to functions other than the dispersion of certain species. There were attempts to bring together several perspectives on the ecological corridor and different disciplines. Empirical studies, literature surveys, monitoring data, theoretical knowledge and modelling studies were all used to create a broader, more comprehensive view of the concept of corridors. When we look at the total process we can certainly conclude that on the level of national policy the shift from ecological corridor to robust corridor may be considered a result of reflection on the ecological basis, of cost–benefit analysis and of the possibilities of linking the corridor concept to other functions such as water management, recreation and cultural identity. In the European context, the ecologists of Alterra explicitly proposed broadening the meaning of the ecological corridor and the network concept from a purely ecological one to what they call 'a spatial concept for multiactor planning of sustainable landscapes' (Opdam, Steingröver & van Rooij 2006).

In the decision-making process and implementation on the regional level, the ecological aspect of the corridor is less visible, however, as is demonstrated by the case of the Green River plan. Here, insights concerning possible functions and designs of ecological corridors developed and altered during the decision-making process as a result of interaction between mainly non-scientific stakeholders.

In conclusion, the success of the ecological corridor cannot be explained by its scientific soundness. Instead, its social robustness seems a better explanation, looking at the process of development, decision-making and implementation in the Netherlands. The power of the ecological corridor concept is related to its vagueness, its flexibility and its metaphorical appeal. The involvement of many stakeholders in early stages of the knowledge-building process was probably an additional important factor making possible practical interaction between several actors and reflection on the meaning of the ecological corridor.

Ecology and policy

As our case study shows, interactions between science and policy were not optimal at several stages of the decision-making process. Here we focus on the possibilities for improvement with regard to the role of ecologists and the structure of policy-making.

In general we may distinguish three positions for ecologists (van der Windt 1990). First, there is the position of the fundamental, academic or autonomous scientist (Swart & Van Andel 2007). If ecologists in this position accept engagement in conservation issues, they will do so only if they can base their recommendations on sound science. This position feels comfortable for most academic ecologists, but in this they run the risk of falling behind the political facts. In other words, this position makes sense only if society is prepared to postpone decisions, waiting for sufficient proof of the soundness of the science concerned. This also implies a willingness on the part of society to improve the quality of scientific recommendations, for instance by increased funding.

Societal engagement is the second position. It implies choosing mainly to be a conservationist, while also taking economic, social, aesthetic and ethical considerations into account. In practice most ecologists make these kinds of choices, at least implicitly (Swart, van der Windt & Keulartz 2001; van der Windt, Swart & Keulartz 2007). In our case examples include the ecologists from conservation organizations defending the Green River plan. This position may be very effective, because scientific information can be included easily in the decision-making process. However, especially in the event of insufficient scientific information, this strategy is also risky because scientific authentication of the recommendations may be unclear (van der Windt 1990; Swart & van Andel 2007). Such a position requires the availability of widely established scientific insight, which occurs rarely in ecological science. A special case in this position is the policy-dependent bureaucrat. Here, ecologists have to follow the demands of politicians to some extent or exchange and link political demands and scientific advice. Ecologists working at the Dutch ministry responsible for nature management are an example of this. This is probably the most difficult position. Although it is easy to influence decision-making, it is difficult to maintain scientific integrity and societal engagement.

Finally there is the position of mediator or translator. Here, the quality of the political and advisory process is most important, as it is expressed by a clear and honest weighing of all interests, values and knowledge. In our case, we found no examples on the regional level, although ecologists working for the authorities in Groningen had an open mind to differing interests and tried to find a compromise for the width of the Green River corridor. This position comes close to what we have labelled 'contextualized science', providing as much scientific knowledge as possible, clarifying types of uncertainties and offering transparency on the scientist's role. It also includes other characteristics of socially robust science: active participation in the extended forum of knowledge production in the decision-making process, a willingness to cope with the knowledge and demands of other parties, reflexivity and multidisciplinarity.

The possibility of choice and the effectiveness of a position depend on personal preferences, affiliation, societal conditions,

scientific domain and the stage of decision-making (van der Windt 1990). Nevertheless, we think that the third position is most appropriate and effective because it is compatible with other positions, as demonstrated by the ecologists of Alterra. In discussions on climate change (Boehmer-Christiansen 1994) and sea management (de Jong 2006), experience with this strategy is already available.

To facilitate this position, interfaces and feedback loops between fundamental ecology, applied ecology and nature policy or management circuits should be developed. It does not mean, however, that the focus should be on only participation, procedures and stakeholders. In the case of the Green River plan, for example, there was a lack of scientific feedback and it is not clear whether similar ecological ends could have been achieved by other means. We believe it is necessary to invest in ecological research related to the decision-making process to reduce the danger of oversimplification of ecological concepts by non-ecologists and to prevent costly conservation failures.

With respect to the improvement of the decision-making structure, we have three more suggestions. First, intermediate research institutes such as Alterra should be more closely involved in the implementation process. These institutes should be independent of the government, organized around ecological problems instead of disciplines, and should position themselves clearly in the network of stakeholder groups, governing bodies and fundamental research institutions to make transfer of insights and perceptions possible. Secondly, during the implementation of ecological concepts such as corridors, intermediate advisory committees with experts from relevant stakeholders and scientific institutions should be installed. Finally, to stimulate integration between nature conservation and other functions, publicly operating regional platforms consisting of scientists, governments, stakeholders and lay people should be established to consider the environmental, economic and social future of the involved region in a transparent way.

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